GLERL Science Strategy

2006
Draft

Contents

GLERL Science Strategic Vision
2006 - 2011

I. Introduction and Rationale

Purpose

This document provides a 5 year strategy for GLERL that will begin in FY2006. It will provide direction to prioritize and evaluate research, to hire and allocate staff, and to allocate resources for the changing needs of NOAA and our Nation's coasts. It is intended to be a living document that may change depending on NOAA priorities and societal need.

What is the Great Lakes Environmental Research Laboratory (GLERL)?

The NOAA Great Lakes Environmental Research Laboratory is one of 7 Federal research laboratories within the Oceanic and Atmospheric Research (OAR) line office of NOAA. GLERL was formed in 1974 to provide a focus for NOAA's environmental and ecosystem research in the Great Lakes. Presently GLERL's research formally resides under NOAA's Ecosystem Goal Team specifically in the Ecosystem Research Program, although the research is applicable to all five of NOAA's goals.   During its history, GLERL has made many important scientific contributions to the understanding and management of the Great Lakes and other coastal ecosystems. GLERL scientists thus play a critical role in academic, state, federal, and international partnerships, and GLERL research provides information and services to support decisions that affect the environment, recreation, public health and safety, and the economy of the Great Lakes and coastal marine environments.

GLERL houses a unique combination of scientific expertise in biogeochemical, hydrological, ecological, physical and biological limnology, and oceanographic sciences. Because of this broad interdisciplinary mix, GLERL is uniquely qualified to focus on ecological forecasting to the NOAA Ecosystem Program. With ecosystem forecasting as a foundation, GLERL's science is dedicated to observing and predicting important characteristics of Great Lakes and coastal marine environments. GLERL's forecasting and tool development for observing and managing the Great Lakes and other coastal marine systems are aimed ultimately toward products that can be transitioned to operations and information services.

GLERL Mission Statement

GLERL conducts high-quality research and provides scientific leadership to understand, observe, assess, and predict the status and changes of Great Lakes and coastal marine ecosystems to educate and advise stakeholders of optimal management strategies.

Ecosystem Forecasting

Definition: *Ecosystem forecasting predicts the effects of biological, chemical, physical, and human-induced changes on ecosystems and their components. These forecasts, both qualitative and quantitative, offer scientifically sound state-of-the-art estimations of likely outcomes.*

NOAA's Great Lakes Environmental Research Laboratory has a long history of addressing a wide range of environmental issues areas (Table 1) in the Great Lakes and other coastal environments. GLERL is the only NOAA research laboratory that has the breadth of scientific expertise to address complex ecosystem Great Lakes issues. GLERL committed to understanding the present state of the Great Lakes ecosystem and also strives to predict impacts of stresses placed on the ecosystem in order to provide information to decision makers that will aid management.

GLERL's long-range research is targeted toward producing a mix of forecasts for a suite of ecological conditions that will advance an ecosystem approach to management that is adaptive, geographically specified, and takes into account ecosystem knowledge and uncertainties (Table 1). These areas were chosen on the basis of value to society, to NOAA, and to management of the Great Lakes.

Table 1. GLERL science issue areas and some major forecasts of concern for the Great Lakes and marine coastal environment

Issue Area	Forecasts
Physical Environment	Offshore Wave Heights
	Coastal Erosion
	Rip Currents
	Nearshore Wave Heights and Condition
	Ice Thickness and Extent
	Spill/search and Rescue
	Storm Surge
	Offshore Currents
	Temperature
Water Quantity	Water Levels
	Tributary Flows
Water Quality	Turbidity/Clarity
	Taste and Odor
	Bacteria Concentration

Human Health	Beach Closings (Bacteria/Pathogens)
	Fish Contamination
	Harmful Algal Blooms
Fish Recruitment and Productivity	Numbers of Fish by Species
	Size of Fish
	Fish Condition
	Fish Distribution
Invasive Species	New Non-Native Species Introductions
	Spread of Introduced Species
	Impact on Ecosystem

Mission Drivers

The Great Lakes are, arguably, the Nations single most important aquatic resource from an economic, geographic, international, ecological, and societal perspective. It is because of this importance that NOAA does research here. NOAA is obligated under multiple statutory drivers (Appendix 1) to pursue research on the Great Lakes to advance our ability to manage this unique resource. The Great Lakes ecosystem is a clearly definable regional entity under NOAA's purview and mission responsibilities and it has a long history of interagency partnerships and collaborations, and thus has the greatest potential for success for testing any regional approaches. GLERL stands as NOAA's representative to fulfill these requirements.

GLERL's mission is also defined by the NOAA Strategic Plan (http://www.spo.noaa.gov/pdfs/FinalMarch31st.pdf), NOAA's 20 Year Research Vision (http://nrc.noaa.gov/Docs/Final_20-Year_Research_Vision.pdf), and 5 Year Research Plan (http://nrc.noaa.gov/Docs/NOAA_5-Year_Research_Plan_010605.pdf). Specifically, GLERL is part of NOAA's ecosystem goal (Goal 1 below). GLERL research also contributes in part to other NOAA strategic plan goals.

NOAA's Mission Goals:

1. **Ecosystem: Protect, restore and manage the use of coastal and ocean resources through ecosystem management approaches**
2. **Climate: Understand climate variability and change to enhance society's ability to plan and respond**
3. **Weather and Water: Serve society's needs for weather and water information**
4. **Commerce & Transportation: Support the Nation's commerce with information for safe and efficient transportation**

Table 2. GLERL's science issue areas support all 4 of **NOAA's Mission Goals (listed above)**.

GLERL's Main Science Issue Areas	NOAA's Mission Goals			
	1	**2**	**3**	**4**
Physical Environment	❖		❖	❖
Water Quantity	❖	❖	❖	❖
Water Quality	❖			
Human Health	❖			
Fish Recruitment and Productivity	❖			
Invasive Species	❖			❖

The Great Lakes region has also led the nation in innovative management strategies that have spanned thousands of miles of coastline over decades, and they provide a large-scale testing ground for new science and management. In its contribution to the 20 Research Vision and the 5 Year Research Plan, GLERL is developing forecasting capabilities that are designed to support an ecosystem approach to planning and management.

Collaboration with Partners and Information Services

GLERL cooperates with a wide range of partners to pursue research that will lead to an ecosystem approach to management. The cooperation includes leadership activities that help address major issues within the Great Lakes such as our work on the Great Lakes Regional Collaboration as outlined by a Presidential Executive Order (No. 13340) to restore and protect the Great Lakes (Great Lakes Regional Collaboration Strategy http://www.glrc.us/documents/GLRC_Strategy.pdf).

GLERL has taken a leadership role in two issue areas of concern by its development of two national centers: The NOAA National Center for Research on Aquatic Invasive Species (NCRAIS) and The NOAA Center of Excellence for Great Lakes and Human Health (CEGLHH). NCRAIS serves as a single point of contact and core of NOAA expertise for partnerships with other agencies and universities on aquatic invasive species. CEGLHH is one three NOAA centers of excellence focusing on multidisciplinary approaches to make forecasts that reduce the risk to human health from water quality problems, harmful pathogens, and harmful algal blooms.

GLERL is also home to NOAA's CoastWatch program for the Great Lakes which produces a number of realtime and retrospective satellite data products. GLERL's forecasting capabilities, e.g., the Great Lakes Forecasting System and lake level forecasts, are the foundation for ecosystem approaches to management. GLERL's outreach services provide education and public awareness about important issues for the Great Lakes. GLERL also interacts with our stakeholders through a SeaGrant extension agent housed at GLERL to provide input for refinement of our research direction and identification of new needs e.g., Great Lakes Ecological Forecasting Needs Assessment, NOAA Technical Memorandum GLERL-131 (ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-131/) and to provide dissemination of GLERL products to our stakeholders. The International Association of

Great Lakes Research and the managing editor of its journal, Journal of Great Lakes Research, are both housed at GLERL. GLERL interacts with the academic community through The GLERL/University of Michigan institute, Cooperative Institute for Limnology and Ecosystems Research (http://ciler.snre.umich.edu/), as well as on an informal basis with most other universities in the Great Lakes basin as needs arise.

II. GLERL's Research by Issue Area

1. Physical Environment

The Issue

Increasing coastal population and economic activities have been accompanied by the need for improved information about the physical environment in coastal areas. Fog, bad weather, high seas, and ice can disrupt navigation and pose a significant hazard for all coastal users. In many cases, the inconvenience and lost productivity are accompanied by the serious threat of injuries and death. Chemical spills, which many times result from inadequate forecasts, can have severe impacts on local ecology, water supplies and human health. Thus, improved forecasting will lead to greater protection, improved economic condition and public safety.

Needs

A review of the current state of environmental prediction clearly shows that over the past 30 years major strides have been made in weather and observing and prediction. The current forecasting system that translates the variations in weather and climate to corresponding responses in the coastal ocean is only beginning to be developed. Major improvements in the capability to link the weather-climate-coastal ocean condition to biological and ecological responses are required for more accurate and comprehensive predictions. To provide effective feedback from the coastal/ocean to the atmosphere and associated weather, substantial improvements in forecasting capabilities are required, and these improvements are under development at GLERL for all physical forecasts in Table 1, which are necessary for daily operational activities, management decisions, long range planning, and regulation in the coastal zone.

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2. Water Quantity

The Issue

Water levels and water quantity in the Great Lakes are major issues because of the damage high water levels and floods can cause to shorelines and shore property and the problems created to navigation and shipping by low water levels. GLERL has a legislative mandate to predict levels and improve forecasting methods (Appendix A). Another important issue is the flow of materials—like bacteria, nutrients, soil, and contaminants—that flow with the water as it moves from land to Great Lakes. As water

flows through the system it transports nutrients, contaminants, soil, and other materials from the land to the lakes. Thus flow of water and these materials must be studied together. Because of sensitivity of lake levels to weather, it is necessary to examine potential climate change scenarios on the hydrology, material flow in watersheds, and water levels.

<div align="center">**Needs**</div>

Successful ecosystem forecasting of water resources requires understanding and forecasting at time scales from hours to years of: the meteorology and hydrology of the Great Lakes watersheds, the meteorology and water and heat balances of the lakes, and the distribution and hydrological transport of various materials within the watersheds. These items entail support activities in the acquisition and processing of spatial and temporal data for land use, soil parameters, elevation, erosion parameters, and near-real time meteorology and for the distribution of nutrients, pesticides, and microbes in the watershed. These items and their support activities will allow us to predict impacts of land management, lake-outflow management, and climate change, as well as to forecast lake levels and related watershed hydrology and the occurrence of beach closings, harmful algal blooms (HAB), and other lake events.

3. Water Quality

<div align="center">**The Issue**</div>

Water quality is a regional, national, and international concern. In the Great Lakes, water quality directly or indirectly impacts nearly every resident of the Great Lakes basin – starting with the 40 million U.S. and Canadian citizens who rely on the Great Lakes for drinking water. The US and Canada have formally cooperated to address water quality problems in the Great Lakes since the signing of the Boundary Waters Treaty in 1909. The Great Lakes Water Quality Agreement (GLWQA 1972, amended 1978, 1987, http://www.epa.gov/glnpo/glwqa/1978/index.html) establishes common water quality objectives for phosphorus, oil, solid waste, and persistent toxic chemicals. The legacy of toxic contamination in the Great Lakes, particularly contaminated sediments, remain a potential risk to aquatic organisms, wildlife, and humans. As a result, 31 U.S. areas of concerns are identified in harbors and tributary areas that have restricted beneficial uses as defined by GLWQA.

While progress towards cleanup has been made in the past 3 decades, diligent attention to water quality and a need for innovative solutions to cleanup remain an important regional priority. Great strides have been made in controlling point sources of new pollutants, but non-point source pollution has grown in its relative contribution to the region's toxic pollution problem. Non-point sources of priority concern include agriculture runoff, urban and suburban runoff, combined sewer overflows, and atmospheric deposition as well as the impact of land use planning and other management decisions on these sources.

Nutrient and toxic contaminant pollution leads to a host of ecological and economic impacts including: fish kills; loss of important and sensitive coastal habitats; excessive and sometimes toxic algal blooms; changes in biodiversity; increases in incidents of human illness; and reductions in tourism.

Since its founding, GLERL has had an active research program in water quality and its modeling efforts have led to cost-effective strategies used by the water quality management community to control phosphorus (P) loading in the Great Lakes. The Great Lakes represent a water quality success story in terms of P abatement and contaminant reductions but certain nearshore areas remain degraded, legacy chemical contamination (sediments) remains in some areas, and new chemicals and pharmaceuticals having potentially negative or unknown effects are increasing.

Needs

Forecasting the impacts of management strategy options on the pace and degree of restoration of the beneficial uses for the Great Lakes as defined by the GLWQA should be considered the highest priority ecological forecasting need relating to Great Lakes water quality. This challenge that will require development of statistical and mechanistic models that include realistic representation of ecosystem processes. Progress in forecasting will require considerable understanding of ecosystem process and development of new models and modeling approaches.

A key part of water quality research is knowledge of the state of the system. GLERL will develop and/or evaluate new technologies for bioassessment programs such as improved sensors to allow survey of important physical variables, oxygen concentration, nutrients, phytoplankton, phytoplankton toxins, zooplankton, and fishes across wide areas of lake surfaces and buoys that provide real-time information on these same variables (See section on Observing Systems).

4. Human Health

The Issue

Human health can be explicitly tied to water quality and despite major advances in the last several decades, the water quality of the Great Lakes remains at risk due to population growth and stresses along the shore line, increased use, climate impacts and emerging contaminants. From a human health perspective, the Great Lakes are the only coastal waters in the Nation used as a source of drinking water. The latest reports on the State of the Great Lakes Ecosystem clearly demonstrate that although the situation has improved from the point of chemical contamination, microbial contaminants remain a threat and need more attention now and in the future.

Until now there has been an exclusive focus on chemical contaminants for human health studies and survey work as part of a Great Lakes human health effects research program. Yet, fecal pollution and microbial contamination continue to be one of the most frequently identified causes of impairment of waters in the Great Lakes Basin. The sources of these microbial contaminants include ballast waters, combined sewer

overflows, sanitary sewage overflows, sewage discharges and biosolids, septic tank discharges, storm waters, animal wastes associated with non-point source pollution, wildlife and hazardous algal blooms (HABs). To address these concerns, NOAA created the Center of Excellence for Great Lakes and Human Health at GLERL. The overall purpose of the Center is to use a multidisciplinary approach to understand and forecast coastal-related human health impacts for public health and natural resource policy and decision-making. The Center builds on existing work at GLERL and throughout NOAA and enhance NOAAs expertise through strong existing and new partnerships.

<u>**Needs**</u>

To develop the connections and forecasts to protect human health a multidisciplinary core of expertise capable of addressing processes in the coastal ecosystem need to be developed and fostered. This core expertise will conduct research, apply new technologies, and develop new capabilities to provide public-domain forecasting models to reduce the human health risk of drinking water, beach closings and harmful algal bloom toxins. The Center of Excellence will provide the focal point for NOAA and academic community research, build internal capacity within NOAA, and develop new and strong partnerships for NOAA with the human health and natural resources communities, the private sector and other federal, state and municipal agencies.
There is also a strong need to provide a program of outreach and education to inform the public and user communities with greater understanding of the processes affecting human health risks.

5. Fish Recruitment and Productivity
<u>**The Issue**</u>

Fisheries in the Great Lakes are critical because of their high commercial ($42 million/year) and sport ($4.3-7.4 billion/year) values and extreme variations in recruitment that are driven by interannual variability in weather, food web disruption from non-indigenous species, changes in nutrient loading, fishing pressure, and habitat change. Perhaps the most serious issue facing management of fisheries resources is the impact of food web disruption and habitat alteration from non-indigenous species. Management of fishery resources is a particular challenge because of our lack of understanding and forecast models for invasive speices impacts on fisheries productivity.

Climate change also challenge forecasting of fisheries productivity. Warmer temperatures could have a potential benefit to fishes because of increased growth rate potential, but there is little understanding of how changes in thermal structure will impact the overall food web that to support the fish due to higher respiration and consumptive demands for prey at warmer temperatures. Likewise, there is poor understanding how interannual variability in weather drives changes in the food web and fishes.

Nutrient loading is in general is decreasing throughout the Great Lakes basin. However, we have little understanding how nutrients move through the system and how this decrease in loading will affect fish recruitment and production.

Needs

Recruitment is a measure of the number of fish entering a size or age class during a given period of time. Important recruitment milestones include (1) recruitment of larval and young of year fishes—typically the most vulnerable stages of a fish's life—to the age-1 year class, (2) recruitment to the fishable size class, and (3) recruitment to the spawning population. Predicting fish recruitment and productivity are the highest priority needs identified by the Great Lakes fishery resource management community (ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-131/). The interaction of all factors nutrients, invasive species, climate change and other natural and anthropogenic stressors need to be modeled to obtain reliable forecasts of fisheries production and recruitment. A comprehensive modeling, field observational, and experimental program is required to make fisheries recruitment and productivity predictions.

6. Invasive Species

The Issue

Invasive species are identified as a leading cause of species extinction and loss of biodiversity in aquatic environments worldwide. Invasive species can replace or eliminate native species, change nutrient and contaminants cycling, affect ecosystem productivity, and can cause losses of economically valuable fisheries. In 1998 there were 1,880 US species classified as imperiled, of which invasive species played a major role in 49% of those listed, second only to habitat loss as a factor, and significantly higher than pollution, overexploitation, and disease combined. In addition to economic and human health costs, nonindigenous invasive species are anticipated to be the leading cause of biodiversity change in lakes in the coming century and of extinctions in North American freshwater ecosystems.

Over 150 species have invaded each of our major coastal environments, such as the Great Lakes, San Francisco Bay, Chesapeake Bay, Gulf of Mexico and the Hawaiian Islands. In each case, exotic species have caused major changes in the local or regional ecology (e.g. food webs, habitats, nutrient and contaminant cycling, fish production) and economy (e.g. commercial and recreational fishing, power production, and drinking water).

Invasive species affect the economic security of our nation's coastal regions. Invasive species have added billions of dollars to the costs of doing business in, or using the natural resources of, affected ecosystems in the U.S. alone. The Great Lakes basin is the aquatic gateway to the heartland of America and a hot spot for aquatic invasive species (AIS) introductions that can reach other sections of the U.S. The earliest recorded aquatic species invasion in the Great Lakes was the sea lamprey, first entering the Great Lakes

from the Atlantic Ocean via the Erie Canal during the 1820s. There are at least 162 AIS in the Great Lakes as of 2001 and twelve of these appear to have entered since 1990. Introduced species are now a significant component of most trophic levels in the Great Lakes.

GLERL has taken a leadership role in two research areas: prevention and developing predictions of the impacts of invasive species in aquatic systems. Further, GLERL is taking a national leadership role through the National Center for Research on Aquatic Invasive Species that helps coordinate NOAA's research in invasive species. The Center is not only concerned with the Great Lakes but marine systems as well. As such it provides a single point of contact and a core of government scientific expertise for partnerships with other agencies and universities on research. In addition to research, GLERL maintains an active outreach program to increase the public's awareness and understanding of non-indigenous species so that it is aware of actions that may be necessary to protect our valuable resources.

Needs

The research necessary to fully address the prevention, control, spread and impacts of invasive species requires broad based programs in toxicology, engineering, biology (particularly invasion biology), and ecology. In part because of limited resources, GLERL focuses its research resources on prevention and impact. To develop effective prevention strategies, the routes of transfer and the mechanisms for inhibition need to be developed. Studies on ballast water and residual water and sediments in "empty" ballast tanks are the major vector of focus for introduction of non-indigenous species in the Great Lakes. This program combines the investigations into the conditions and species transported in ballast water and development of tools to eliminate potential invader organisms in ballast tanks. Prediction of impacts is the key to developing adaptive management strategies for the resource management community. GLERL has ongoing programs examining the impacts of food web disruption and the promotion harmful algal blooms (*Microcystis*) in the Great Lakes. Further details of these programs can be found at http://www.glerl.noaa.gov/res/Programs/ais/). NCRAIS fosters the research in other parts of NOAA to expand and fill in the components of a program necessary for the broader invasive species research program.

III. Great Lakes Observing System—A Necessary Component of a Forecasting Strategy

The Issue

Successful ecosystem forecasting and validation depend on the availability of data describing the present state of the Great Lakes at a variety of time and space scales. Observing baseline ecological and environmental parameters is the key to developing the

understanding and process information needed to develop prediction models for such stressors as climate change, population growth along the coastal zone, and exploitation of natural resources on the ecosystem. An observation network that provides the time and space scales necessary to track ecosystem process and provide the data in a timely manner is required to establish both the initial conditions and verification of forecast models. Current systems are limited in the range of variables that can be observed and timing and rate of data transfer. New and more sensitive sensors will be needed along with improved data management systems to fully meet the needs of the forecasting community.

Needs

An integrated Great Lakes Observing System is needed to provide real-time observations of chemical, biological, and physical variables. The system will allow data collection during extreme weather events, facilitate modification of sampling variables in anticipation of episodic events, facilitate collection of biological and physical samples in response to episodic events, and support long term research. This includes needs for the development of new low-cost coastal buoys capable of seabed to sea-surface observations with access to real-time data. The observing system network will allow system growth to meet forecast requirements through a high bandwidth, wireless Ethernet-based buoy system; real-time, secure data access; portable, low cost buoys and fixed platforms of opportunity; universal sensor interfaces; guest port access. The data need to be delivered in common formats to support partnerships with Federal, University, and State organizations. The data will also need to be collected and stored with new improved data management systems to insure that the data are available now and in the future in easily retrieved formats. New systems such as autonomous underwater vehicles and real-time *in situ* biological and chemical sensors, including fisheries acoustics for biomass estimation are required to support the Ocean US coastal priorities. Quality Assurance/Quality Control (QA/QC) programs for all data will need to be developed. In particular, new approaches for QA/QC will be developed for chemical and biological data in collaboration with the Alliance for Coastal Technologies program. The research will establish a test bed for observing system network design and develop enhanced verification capabilities as outlined in NOAA's 5 Year Research Plan.

IV. Implementation of GLERL's Strategic Vision

GLERL research is use-oriented (mission-driven) ultimately leading to important management applications, operational tools or forecasts, or increased public awareness in one of GLERL's Science Issue Areas. GLERL's pre-eminence depends on focused research leading to useful forecasts and a taking leadership role in these issue areas that align with our legislative (national and international) mandates, NOAA Ecosystem Program Goals, and partnerships with the Great Lakes and academic communities.

The Strategic Matrix

The strategic matrix (shown below) gives an illustration of how progress is made for selected predictions in different issue areas through a series of fundamental activities from identification of an issue to an application or a forecast that is transitioned to operations or to a forecast that educates or advises stakeholders of appropriate management strategies. Each step in the matrix could result in a NOAA Program Milestone. It is not possible in this simple format to lay out the specific paths taken for each prediction as they often involve detours as unsuspected discoveries are made along the way. These discoveries themselves may then open up a need for a new forecast.

Internal GLERL research funds and human resources are distributed to GLERL projects on the basis of a competitive internal proposals whose merit is decided by relevance of the proposed forecast to the GLERL mission, its scientific merit, and productivity of the GLERL project personnel. Proposals that are multidisciplinary and focus on larger questions in the Science Issue Areas are given priority. Proposals developed with other NOAA line offices, other agencies (such as EPA, NSF, Great Lakes Fisheries Commission) and university partners are encouraged and can leverage funds to answer important questions or lead to important forecasts in the GLERL science issue areas. In the examples given below, many of the physical forecasts are further along the matrix than more ecological forecasts, e.g., the new project on larval recruitment. This is in part because of the scope and complexity of the question, the state of development of the science, the interdisciplinary nature of ecological problems, the field and experimental work that must be done, and the development of an ecological model that must integrate results and models from nearly all issue areas.

V. Summary Statement—The Importance of Human Capital

The goal of this document is to provide guidance in resource allocation, in tactical and strategic program development, and in staffing at GLERL by aligning our forecasting mission with the needs of NOAA, other stakeholders, and mission drivers. A combination of alignment and excellence of research are they keys to success. In achieving excellence, GLERL recognizes the need to invest in its most important resource, its staff. GLERL fosters an environment of excellence through encouragement

of inquiry into important problems and fosters an environment of cooperation and teamwork required for today's interdisciplinary problems needed for an ecosystem approach to management. Indeed this attitude aligns with NOAA core values stressing people, integrity, excellence, teamwork, ingenuity, science, service, and stewardship. We believe that this enlightened approach will lead to a better world through environmental and ecological knowledge and stewardship to create NOAA's Vision: "An informed society that uses comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions."

The Strategic Matrix, an idealized view of how a **forecast of interest to the user communit**y would be developed and transitioned to operations. The X's in the matrix imply how far the forecast of interest is in the development process. The table below gives a few specific examples of GLERL's work.

Forecast	Identify key variables and processes	Build preliminary model (pose hypotheses)	Observe key state variables	Measure key processes (do experiments to test hypotheses)	Compare model with observations (evaluate hypotheses)	Refine model by doing more experiments	Transition to operations or complete product
Coastal Environmental Predictions:							
Offshore waves, temperature, currents	X	X	X	X	X	X	X
Nearshore waves, temperature, (rip)currents, storm surge	X	X	X	X	X		
Great Lakes ice coverage	X	X	X	X	X		
Spill/Search and rescue trajectories	X	X	X	X	X	X	X
Vertical thermal structure in Lake Erie	X	X	X	X			
Bacterial transport in nearshore L. Michigan	X	X	X	X			

Strategic Matrix continued

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| Forecast/Tool | **NOAA Approach: Monitor and Observe → Understand and Describe→ Assess and Predict → Engage and Advise → Manage** Scientific Method: Observation → Hypothesis → Experiment → Explanation | | | | | | |

Forecast/Tool	**Identify key variables and processes**	**Build preliminary model (pose hypotheses)**	**Observe key state variables**	**Measure key processes (do experiments to test hypotheses)**	**Compare model with observations (evaluate hypotheses)**	**Refine model by doing more experiments**	**Transition to operations or complete product**
Water Resources:							
6-month forecast of water levels in Great Lakes	X	X	X	X	X	X	X
Water flow & nutrient loading into western L. Erie	X	X	X	X			
Flooding in Great Lakes tributaries	X	X	X	X	X		
Water Quality:							
Turbidity, taste & odor, nearshore vegetation.	X	X					
Bacterial & toxic chemical concentrations in water	X	X					
Bioaccumulation of Legacy chemicals from sediments	X	X	X	X	X		

Strategic Matrix continued

Forecast/Tool	Identify key variables and processes	Build preliminary model (pose hypotheses)	Observe key state variables	Measure key processes (do experiments to test hypotheses)	Compare model with observations (evaluate hypotheses)	Refine model by doing more experiments	Transition to operations or complete product
NOAA Approach: Monitor and Observe → Understand and Describe→ Assess and Predict → Engage and Advise → Manage							
Scientific Method: Observation → Hypothesis → Experiment → Explanation							
Human Health:							
Beach closings	X	X	X				
Early warning system for HABS	X	X	X	X	X		
Microcystin (toxin) levels in Lake Erie fish	X	X	X				
Fish recruitment and productivity							
Yellow perch recruitment in western Lake Erie	X	X					
Fish production in Lake Erie as function of extent of dead zone	X	X	X				

Strategic Matrix continued

Forecast/Tool	Identify key variables and processes	Build preliminary model (pose hypotheses)	Observe key state variables	Measure key processes (do experiments to test hypotheses)	Compare model with observations (evaluate hypotheses)	Refine model by doing more experiments	Transition to operations or complete product
NOAA Approach: Monitor and Observe → Understand and Describe→ Assess and Predict → Engage and Advise → Manage							
Scientific Method: Observation → Hypothesis → Experiment → Explanation							
Non-indigenous species							
Decrease in alewife recruitment caused by food web disruption as related to cercopagid abundance	X	X	X	X			
HAB severity in Great Lakes as related to variations in dreissenid abundance	X	X	X	X			

VI. Appendix A—GLERL's Legislative Mandates

<u>33 U.S.C. § 1268   ESTABLISHMENT OF GREAT LAKES RESEARCH OFFICE</u>

There is established within the National Oceanic and Atmospheric Administration the Great Lakes Research Office. The Research Office shall conduct, through the *Great Lakes Environmental Research Laboratory*, the National Sea Grant College program, other Federal laboratories, and the private sector, appropriate research and monitoring activities which address priority issues and current needs relating to the Great Lakes.

The Research Office shall identify issues relating to the Great Lakes resources on which research is needed. The Research Office shall submit a report to Congress on such issues before the end of each fiscal year which shall identify any changes in the Great Lakes system \2\ with respect to such issues.

This section relates to water and lake sediment contaminants

<u>16 U.S.C. § 1447B—REGIONAL MARINE RESEARCH PROGRAMS</u>

[Laws in effect as of January 7, 2003

"The purpose of this chapter is to establish regional research programs, under effective Federal oversight, to--
(1) set priorities for regional marine and coastal research in support of efforts to safeguard the water quality and ecosystem health of each region; and
(2) carry out such research through grants and improved coordination."
(a) Establishment

A Regional Marine Research board \1\ shall be established for each of the following regions:

(1) the Gulf of Maine region, comprised of the marine and coastal waters off the State of Maine, New Hampshire, and Massachusetts (north of Cape Cod);
(2) the greater New York bight region, comprised of the marine and coastal waters off the States of Massachusetts (south of Cape Cod), Rhode Island, Connecticut, New York, and New Jersey, from Cape Cod to Cape May;
(3) the mid-Atlantic region, comprised of the marine and coastal waters off the States of New Jersey, Delaware, Maryland, Virginia, and North Carolina, from Cape May to Cape Fear;
(4) the South Atlantic region, comprised of the marine and coastal waters off the States of North Carolina, South Carolina, Georgia, and Florida, from Cape Fear to the Florida

Keys, including the marine and coastal waters off Puerto Rico and the United States Virgin Islands;

(5) the Gulf of Mexico region, comprised of the marine and coastal waters off the States of Florida, Alabama, Mississippi, Louisiana, and Texas, along the Gulf coast from the Florida Keys to the Mexican border;

(6) the California region, comprised of the marine and coastal waters off the State of California, from Point Reyes to the Mexican border;

(7) the North Pacific region, comprised of the marine and coastal waters off the States of California, Oregon, and Washington, from Point Reyes to the Canadian border;

(8) the Alaska region, comprised of the marine and coastal waters off the State of Alaska; and

(9) insular Pacific region, comprised of the marine and coastal waters off the State of Hawaii, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

The Great Lakes Research Office authorized under section 1268(d) of title 33 shall be responsible for research in the Great Lakes region and shall be considered the Great Lakes counterpart to the research program established pursuant to this chapter.

(b) Membership

 (1) Composition

  Each Board shall be comprised of 11 members of which—

   (A) 3 members shall be appointed by the Administrator of the National Oceanic and Atmospheric Administration, including 1 member who shall be a Sea Grant Program Director from a State within such region, who shall serve as chairman of the board;
   (B) 2 members shall be appointed by the Administrator of the Environmental Protection Agency; and
   (C) 6 members shall be appointed by Governors of States located within the region.

(2) Qualifications

 Each individual appointed as a member of a Board shall possess expertise, pertinent to the region concerned, in scientific research, coastal zone management, fishery management, water quality management, State and local government, or any other area which is directly relevant to the functions of the Board. A majority of the members of each Board shall be trained in a field of marine or aquatic science and shall be currently engaged in research or research administration.

15 U.S.C. § 1511   COMMERCE AND TRADE

"Sec. 2901. Findings

The following are hereby transferred to the Secretary of Commerce:

  (e) Those functions vested in the Secretary of Defense or in any officer, employee, or organizational entity of the Department of Defense by the provision of Public Law 91-144, 83 Stat. 326, under the heading
``……. (2) the conception, planning, and conduct of basic research and development in the fields of water motion, water characteristics, water quantity, and ice and snow, and (3) the publication of data and the results of research projects in forms useful to the Corps of Engineers and the public, and the operation of a Regional Data Center for the collection, coordination, analysis, and the furnishing to interested agencies of data relating to water resources of the ***Great Lakes***."

16 U.S.C. § 4741--CONSERVATION

Sec. 4701. Findings and purposes

"(a) Findings

The Congress finds that--
(1) the discharge of untreated water in the ballast tanks of vessels and through other means results in unintentional introductions of nonindigenous species to fresh, brackish, and saltwater environments;
(2) when environmental conditions are favorable, nonindigenous species become established, may compete with or prey upon native species of plants, fish, and wildlife, may carry diseases or parasites that affect native species, and may disrupt the aquatic environment and economy of affected nearshore areas;
(3) the zebra mussel was unintentionally introduced into the Great Lakes and has infested—
(A) waters south of the Great Lakes, into a good portion of the Mississippi River drainage;
(B) waters west of the Great Lakes, into the Arkansas River in Oklahoma; and
(C) waters east of the Great Lakes, into the Hudson River and Lake Champlain;
(4) the potential economic disruption to communities affected by the zebra mussel due to its colonization of water pipes, boat hulls and other hard surfaces has been estimated at $5,000,000,000 by the year 2000, and the potential disruption to the diversity and abundance of native fish and other species by the zebra mussel and ruffe, round goby, and other nonindigenous species could be severe;

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(5) the zebra mussel was discovered on Lake Champlain during 1993 and the opportunity exists to act quickly to establish zebra mussel controls before Lake Champlain is further infested and management costs escalate;

(6) in 1992, the zebra mussel was discovered at the northernmost reaches of the Chesapeake Bay watershed;

(7) the zebra mussel poses an imminent risk of invasion in the main waters of the Chesapeake Bay;

(8) since the Chesapeake Bay is the largest recipient of foreign ballast water on the East Coast, there is a risk of further invasions of other nonindigenous species;

(9) the zebra mussel is only one example of thousands of nonindigenous species that have become established in waters of the United States and may be causing economic and ecological degradation with respect to the natural resources of waters of the United States;

(10) since their introduction in the early 1980's in ballast water discharges, ruffe--

(A) have caused severe declines in populations of other species of fish in Duluth Harbor (in Minnesota and Wisconsin);

 B) have spread to Lake Huron; and

(C) are likely to spread quickly to most other waters in North America if action is not taken promptly to control their spread;"

"(b) Purposes

The purposes of this chapter are—

(1) to prevent unintentional introduction and dispersal of nonindigenous species into waters of the United States through ballast water management and other requirements;

(2) to coordinate federally conducted, funded or authorized research, prevention \1\ control, information dissemination and other activities regarding the zebra mussel and other aquatic nuisance species;

(3) to develop and carry out environmentally sound control methods to prevent, monitor and control unintentional introductions of nonindigenous species from pathways other than ballast water exchange;

(4) to understand and minimize economic and ecological impacts of nonindigenous aquatic nuisance species that become established, including the zebra mussel; and

(5) to establish a program of research and technology development and assistance to States in the management and removal of zebra mussels."

" (1) $1,625,000, which shall be made available from funds otherwise authorized to be appropriated if such funds are so authorized, to fund aquatic nuisance species prevention and control research under section 4722(i) of this title at the ***Great Lakes Environmental Research Laboratory*** of the National Oceanic and Atmospheric Administration, of which $500,000 shall be made available for grants, to be competitively awarded and subject to peer review, for research relating to Lake Champlain"

``(3) $1,125,000 to fund aquatic nuisance species prevention and control research under section 4722(i) of this title at *the Great Lakes Environmental Research Laboratory* of the National Oceanic and Atmospheric Administration;

16 U.S.C. § 4722. AQUATIC NUISANCE SPECIES PROGRAM

The Assistant Secretary, in consultation with the Task Force, shall investigate and identify environmentally sound methods for preventing and reducing the dispersal of aquatic nuisance species between the Great Lakes-Saint Lawrence drainage and the Mississippi River drainage through the Chicago River Ship and Sanitary Canal, including any of those methods that could be incorporated into the operation or construction of the lock system of the Chicago River Ship and Sanitary Canal.

The *Great Lakes Environmental Research Laboratory* of the National Oceanic and Atmospheric Administration shall provide technical assistance to appropriate entities to assist in the research conducted pursuant to this subsection.

16 U.S.C. § 760e – STUDY OF MIGRATORY GAME FISH; WATERS; RESEARCH PURPOSE

"The Secretary of Commerce is directed to undertake a comprehensive continuing study of migratory marine fish of interest to recreational fishermen of the United States,….including fish which migrate through or spend part of their lives in the inshore waters of the United States. The study shall include, but not be limited to, research on migrations, identity of stocks, growth rates, mortality rates, variation in survival, environmental influences, both natural and artificial, including pollution and effects of fishing on the species for the purpose of developing wise conservation policies and constructive management activities."

42 U.S.C. § 7412—PUBLIC HEALTH & WELFARE—POLLUTION PREVENTION AND CONTROL

" The Administrator, in cooperation with the Under Secretary of Commerce for Oceans and Atmosphere, shall conduct a program to identify and assess the extent of atmospheric deposition of hazardous air pollutants (and in the discretion of the Administrator, other air pollutants) to the **Great Lakes**, the Chesapeake Bay, Lake Champlain and coastal waters. As part of such program, the Administrator shall—
(A) monitor the **Great Lakes**, the Chesapeake Bay, Lake Champlain and coastal waters, including monitoring of the **Great Lakes** through the monitoring network established pursuant to paragraph (2) of this subsection and designing and deploying an atmospheric monitoring network for coastal waters pursuant to paragraph (4);
(B) investigate the sources and deposition rates of atmospheric deposition of air pollutants (and their atmospheric transformation precursors);

(C) conduct research to develop and improve monitoring methods and to determine the relative contribution of atmospheric pollutants to total pollution loadings to the **Great Lakes**, the Chesapeake Bay, Lake Champlain, and coastal waters;"

15 U.S.C. §§ 1525, 1540—COOPERATIVE AGREEMENTS/REIMBURSEMENT TO FURTHER NOAA'S MISSION

Memorandum of Understanding between The Environmental Research Laboratories of the National Oceanic and Atmospheric Administration and the University of Michigan -- Revision of 7/11/89.

"The environmental Research Laboratories (ERL) of the National Oceanic and Atmospheric Administration (NOAA) have collaborated for a number of years with the University of Michigan and Michigan State University in limnological and environmental research. This Memorandum of understanding (MOU) between NOAA and the University of Michigan reaffirms their common interest in these research areas and provides a basis for future cooperative research efforts. ….. 2. Improve the effectiveness of graduate-level education and expand the scientific experiences available to graduate students by providing a central vehicle for their participation in joint research programs with the **Great Lakes Environmental Research Laboratory. …..2**) Assist in he coordination of research accomplished in **GLERL… 1) Facilitate the establishment of joint research projects between scientists"**

15 U.S.C. § 2901—NATIONAL CLIMATE PROGRAM ACT

Sec. 2901. Findings

"The Congress finds and declares the following:
(1) Weather and climate change affect food production, energy use, land use, water resources and other factors vital to national security and human welfare.
(2) An ability to anticipate natural and man-induced changes in climate would contribute to the soundness of policy decisions in the public and private sectors.
(3) Significant improvements in the ability to forecast climate on an intermediate and long-term basis are possible.
(4) Information regarding climate is not being fully disseminated or used, and Federal efforts have given insufficient attention to assessing and applying this information.
(5) Climate fluctuation and change occur on a global basis, and deficiencies exist in the system for monitoring global climate changes. International cooperation for the purpose of sharing the benefits and costs of a global effort to understand climate is essential.
(6) The United States lacks a well-defined and coordinated program in climate-related research, monitoring, assessment of effects, and information utilization." …..

 ``(b) Formulation of United States Policy.--The President, through the Environmental Protection Agency, shall be responsible for developing and proposing to Congress a

coordinated national policy on global climate change. Such policy formulation shall consider research findings of the Committee on Earth Sciences of the Federal Coordinating Council on Science and Engineering Technology, the National Academy of Sciences, the National Oceanic and Atmospheric Administration,…."

33 U.S.C. § 145—HARMFUL ALGAL BLOOM AND HYPOXIA RESEARCH AND CONTROL ACT OF 1998

"(10) the National Oceanic and Atmospheric Administration, through its ongoing **research**, education, grant, and coastal resource management programs, possesses a full range of capabilities necessary to support a near and long-term comprehensive effort to prevent, reduce, and **control** harmful algal blooms and **hypoxia**;
``(11) funding for the **research** and related programs of the National Oceanic and Atmospheric Administration will aid in improving the Nation's understanding and capabilities for addressing the human and environmental costs associated with harmful algal blooms and **hypoxia**; and…"

33 U.S.C. § 1268--NAVIGATION AND NAVIGABLE WATERS--WATER POLLUTION PREVENTION AND CONTROL--RESEARCH AND RELATED PROGRAMS

"The Congress finds that--
(A) the Great Lakes are a valuable national resource, continuously serving the people of the United States and other nations as an important source of food, fresh **water**, recreation, beauty, and enjoyment;
(B) the United States should seek to attain the goals embodied in the Great Lakes **Water Quality Agreement** of 1978, as amended by the **Water Quality Agreement** of 1987 and any other agreements and amendments, with particular emphasis on goals related to toxic pollutants; and…"

33 U.S.C. §2326b-NAVIGATION AND NAVIGABLE WATERS--WATER RESOURCES DEVELOPMENT

"The Secretary (*of Commerce*) may enter into cooperation agreements with non-Federal interests with respect to navigation projects, or other appropriate non-Federal entities, for the development of long-term management strategies for controlling sediments at such projects."

Studies conducted at GLERL for CORPS with regards to dredging

GREAT LAKES WATER QUALITY AGREEMENT OF 1978—AMENDED 1987

International Agreement between Canada and the United States which involves restoring and enhancing water quality in the Great Lakes System

"Implementation: The Parties, in cooperation with State and Provincial Governments, shall conduct research in order to:

a) Determine the mass transfer of pollutants between the Great Lakes basin Ecosystem components of water, sediment, air, land and biota, and the processes controlling the transfer of pollutants across the interfaces between these components in accordance with Annexes 13,14, 15, and 16;

b) Develop load reduction models for pollutants in the Great Lakes System in accordance with the research requirements of Annexes 2, 11, 12, and 13;

c) Determine the physical and transformational processes affecting the delivery of pollutants by tributaries to the Great Lakes in accordance with Annexes 2,11,12,13;

d) Determine cause-effect inter-relationships of productivity and ecotoxicity, and identify future research needs in accordance with Annexes 11, 12, 13 and 15;

e) Determine the relationship of contaminated sediments on ecosystem health, in accordance with the research needs of Annexes 2, 12 and 14;

f) Determine the pollutant exchanges between the Areas of Concern and the open lakes including cause-effect inter-relationships among nutrients, productivity, sediments, pollutants, biota and ecosystem health, and to develop in-situ chemical, physical and biological remedial options in accordance with Annexes 2, 12,14, and sub-paragraph 1(f) of Annex 3;

g) Determine the aquatic effects of varying lake levels in relation to pollution sources, particularly respecting the conservation of wetlands and the fate and effects of pollutants in the Great Lakes Basin Ecosystem in accordance with Annexes 2, 11, 12, 13, 15, and 16;

h) Determine the ecotoxicity and toxicity effects of pollutants in the development of water quality objectives in accordance with Annex 1;

i) Determine the impact of water quality and the introduction of non-native species on fish and wildlife population and habitats in order to develop feasible options for their recovery, restoration or enhancement in accordance with sub-paragraph 1(a) of Article IV and Annexes 1,2,11 and 12;

j) Encourage the development of control technologies for treatment of municipal and industrial effluents, atmospheric emissions and the disposal of wastes, including wastes deposited in landfills;

k) Develop action levels for contamination that incorporate multi-media exposures and the interactive effects of chemicals; and

l) Develop approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health.

15 U.S.C. § 1525--COMMERCE AND TRADE--DEPARTMENT OF COMMERCE

"The Secretary of Commerce is authorized, upon the request of any person, firm, organization, or others, public or private, to make special studies on matters within the authority of the Department of Commerce; to prepare from its records special compilations, lists, bulletins, or reports; to perform the functions authorized by section 1152 of this title; and to furnish transcripts or copies of its studies, compilations, and other records; upon the payment of the actual or estimated cost of such special work."